July 1948 E-750

United States Department of Agriculture
Agricultural Research Administration
Bureau of Entomology and Plant Quarantine

SOIL TREATMENTS WITH DDT TO CONTROL THE WHITE-FRINGED BEETLE

H. C. Young and J. B. Gill
Division of Cereal and Forage Insect Investigations[1]/

The use of DDT as a soil insecticide for the control of the white-fringed beetle (Graphognathus leucoloma fecundus Buch.) has been studied at Florala, Alabama, since 1943. Experiments have been conducted with larvae of different ages in earthenware pots, with newly hatched larvae in outdoor soil chambers, and with natural populations in field plots. The DDT was a factory-ground dust containing either 10 or 50 percent of DDT in pyrophyllite. The soil used in the pot and chamber tests was Tifton fine sandy loam, and the field plots were on Norfolk and Tifton fine sandy loam soils.

Pot Tests

In pot tests conducted in 1943 and 1944, the lowest dosage was 10 pounds of DDT in 403.3 cubic yards of soil (the upper 3 inches of an acre of soil), but in 1945 and 1946 dosages as low as 1 pound were used. The soil was placed in 6-inch standard earthenware pots, the drain holes of which were covered with 60-mesh brass-wire cloth to prevent escape of larvae. The DDT was thoroughly mixed with the soil, and larvae were confined within the pots throughout the test period. Since it was treated the soil has been continuously exposed to outside weathering.

Dosages of 5 pounds or more of DDT gave complete mortality of newly hatched larvae installed in August following treatment of the soil in July. Dosages of 1 and 2½ pounds gave appreciable control, but failed to give complete mortality in a number of tests.

DDT is more effective against newly hatched white-fringed beetle larvae than against older larvae. In tests started in October with partially grown but immature larvae, dosages of 50 pounds gave complete mortality by the following June. Dosages of 10 and 25 pounds gave 97 and 99 percent control, respectively. The lighter dosages, 1 to 5 pounds, gave 61 to 85 percent control.

When immature larvae were installed in treated soil in February, a 50-pound dosage of DDT gave complete mortality by June. The 10- and 25-pound dosages gave 85 and 98 percent control, respectively. The 2½- and 5-pound dosages gave control ranging from 29 to 59 percent, and the 1-pound dosage gave no control.

1/ In cooperation with the Alabama Department of Agriculture and Industries.

When immature larvae were installed in treated soil in late April or early May, a dosage of 100 pounds of DDT failed to give complete mortality after 30 to 37 days. Dosages of 25, 50, and 100 pounds gave better than 90 percent control. Reduced dosages gave much less control.

Soil treatments with DDT retard larval development. In numerous tests it was observed in late May and early June that a much larger percentage of individuals had pupated in the untreated checks than in the treated pots.

Mature larvae are more resistant to DDT in soil treatments than are immature larvae. In tests started February 15 dosages up to 50 pounds of DDT gave no appreciable mortality of mature larvae by April 15. A dosage of 50 pounds gave only 60 percent control by May 28, and lesser dosages gave no control. When mature larvae were installed in late April or early May, dosages up to 50 pounds of DDT caused no mortality in a 30- to 37-day test period, but pupation was delayed.

Dosages of 10, 25, 50, 100, and 250 pounds of DDT applied to soil in 1943 and 1944 gave complete mortality of newly hatched larvae installed in the same year and in subsequent years including 1946. Dosages of 5 to 50 pounds of DDT gave complete mortality of similar larvae installed in 1945 and 1946. A 2½-pound dosage gave 99 percent control the first year and 86 percent the second year. A 1-pound dosage gave 71 percent control the first year but no control the second year. Light dosages of DDT decreased in effectiveness within 2 years after application.

Outdoor Soil Chamber Tests

In 1945 an experiment was started in outdoor soil chambers to study the effectiveness of DDT as a soil insecticide against the white-fringed beetle. The chambers were made of galvanized sheet iron and were 14-7/8 inches square by 22½ inches deep, without bottoms. They were set into the ground nearly to their full depth, and covered with screen-wire cages to prevent infestation other than that desired and to retain adults that emerged. The chambers were filled with subsoil and top soil in their natural positions to the level of the soil outside. Suitable plants were kept growing in the chambers to serve as food for the larvae. DDT was applied at rates of 2½, 5, 10, 25, 50, and 100 pounds per acre. Each dosage was applied in three ways--(1) on the surface of the soil, (2) mixed with the upper 3 inches of soil, and (3) mixed with the upper 6 inches of soil. The DDT was applied in July 1945, the chambers were infested with newly hatched larvae in August, and the daily adult emergence was recorded in 1946. When the DDT was mixed with the soil, it was more effective than when placed on the soil surface. No adults emerged in the chambers treated in this way at 10 pounds or more per acre. There was some emergence at all dosages where the DDT was placed on the surface of the soil.

These chambers were reinfested with newly hatched larvae in 1946 without further DDT treatments, and the daily adult emergence was recorded in 1947. As in the previous year, all dosages of 10 pounds or more of DDT per acre when mixed in the soil gave complete mortality. Some adults emerged in the chambers receiving surface treatments at rates of 2½ to 50 pounds of DDT per acre. The 2½-pound dosage mixed into the soil was less effective in the second year than in the first.

The DDT treatments delayed emergence of adults. In 1946 the emergence was 14 days earlier, and in 1947, 8 days earlier, in the untreated chambers than in the DDT-treated chambers.

Field-Plot Treatments

Tests begun in 1945.—In the field-plot tests begun in 1945 the DDT was mixed with the fertilizer at rates of 1½ and 3 pounds per acre and applied in the drill rows just prior to planting. There were two replicates of each treatment in each of two fields. A heavy larval population (146 per square yard) existed in one field, and a low population (38 per square yard) in the other. Both fields were planted to corn. In the field with the heavy population only one-fifth as many corn plants were killed by white-fringed beetle larvae in the treated plots as in the adjoining untreated plots. The treated plots had 96 percent of a full stand as compared with only 82 percent in the check plots. The treated plots produced an average of 510 pounds of ear corn per acre, or 40 percent, more than the untreated plots. Both dosages were approximately equally effective in preventing damage to the corn. In the field with the light population only 0.4 percent of the corn plants were killed by beetle larvae, and the yields were approximately the same in the treated and in the untreated plots.

The DDT treatments caused a reduction in the subsequent larval population. In January 1946 the population in the corn drills in the treated plots was lower than at other points in the same plots, and lower than at all points in the untreated plots. The greatest reduction in population occurred along the corn rows where the DDT was applied.

No further DDT treatments have been made in these plots since 1945, but records of damage, yields, and larval populations have been continued. In the field with the low initial population the larval population has continued low, and no appreciable damage occurred in 1946 or 1947. In 1946 the yield of peanuts was slightly greater in the untreated check plots than in the plots receiving the DDT treatments, and in 1947 the yield of cotton was slightly greater in the plots receiving the DDT treatments than in the untreated check plots.

The experimental area with the high initial larval population was planted to cotton in 1946. White-fringed beetle larvae killed twice as many plants in the untreated check plots (16.6 percent) as in the plots receiving the DDT treatments. No yield records were secured on the cotton in 1946. The plots of this test were planted to corn intercropped with velvetbeans in 1947. The larval damage to the corn was light in all plots, but the loss of velvetbean plants due to beetle larvae was three times as great in the untreated check plots as in the plots receiving the DDT treatments. The yield of corn was slightly higher in the plots receiving the DDT treatments than in the untreated check plots.

DDT treatments applied in the drill rows in 1945 had no effect on the larval populations as determined in January 1947. Larval populations were as great in the plots receiving the DDT treatments as in the untreated check plots in both tests.

Tests begun in 1946.--Fourteen field-plot tests, including 126 plots, were started in 1946 to study the effectiveness of DDT as a soil insecticide against white-fringed beetle larvae. Each test consisted of 9 plots arranged as a 3 by 3 Latin square. Before the crop was planted, DDT was broadcast over the surface and immediately worked into the soil with a tractor disk, or was applied in a narrow band directly in the drill rows and covered by the fertilizer distributor or planter. Two rates of application were used--$2\frac{1}{2}$ and 5 pounds of DDT per acre. The crops involved included corn with no intercrop, corn intercropped with velvetbeans, cotton, and peanuts.

In 5 tests including 45 plots (15 replicates of each treatment rate) DDT was applied directly in the drill rows and the plots were planted to corn intercropped with velvetbeans. The larval population at planting time averaged 118 per square yard. The average loss of stand to corn caused by white-fringed beetle larvae was 2.8 percent in the untreated check plots, and 0.2 percent in the plots treated with DDT at either dosage. The DDT treatments caused a highly significant reduction in the number of corn plants killed by white-fringed beetle larvae. The average yield of ear corn in the plots receiving the $2\frac{1}{2}$-pound DDT treatment was 106 pounds per acre higher than in the untreated check plots, whereas in the plots receiving the 5-pound treatment there was a significant increase of 189 pounds per acre.

In four of the five tests planted to corn intercropped with velvetbeans the drill rows of the velvetbeans were treated with DDT. Larval damage was much greater to the velvetbeans than to the corn. The average loss of velvetbean stand due to beetle larvae was 30.9 percent in the untreated check plots, 3.5 percent in the plots receiving the $2\frac{1}{2}$-pound DDT treatment, and 3.9 percent in the plots receiving the 5-pound treatment.

In one of the five tests planted to corn intercropped with velvetbeans the drill rows of the velvetbeans were not treated with DDT. The corn rows were 5.72 feet apart, and the velvetbean rows were midway between the corn rows. The DDT treatments applied in the corn drills had no effect on larval damage to the velvetbeans.

In 4 tests including 36 plots (12 replicates of each treatment rate) DDT was applied broadcast. The initial larval population averaged 52 per square yard, and the average loss of corn stand due to white-fringed beetle larvae was 3 percent in the untreated check plots, 0.2 percent in the plots receiving the $2\frac{1}{2}$-pound DDT treatment, and none in the plots receiving the 5-pound treatment. The $2\frac{1}{2}$-pound dosage of DDT gave an average gain of 105 pounds and the 5-pound dosage an average gain of 195 pounds of ear corn per acre over the untreated check plots.

Corn was planted in 9 tests including 81 plots (27 replicates of each treatment rate) in which DDT was used as a soil insecticide in 1946. The plots in 5 tests received drill treatments and the plots in 4 tests received broadcast treatments. The initial larval population at planting time in all plots averaged 89 per square yard. The average loss of stand due to white-fringed beetle larvae was 3 percent in the untreated check plots, 0.2 percent in the plots receiving the $2\frac{1}{2}$-pound DDT treatment, and 0.1 percent in the plots receiving the 5-pound treatment. The $2\frac{1}{2}$-pound dosage of DDT gave an average gain of 106 pounds and the 5-pound dosage an average gain of 192 pounds of ear corn per acre over the untreated check plots.

Cotton was planted in the plots of 3 tests (27 plots and 9 replicates of each treatment rate) in which the DDT was applied in the drill rows. The initial larval population just prior to planting averaged 112 per square yard. Both dosages, 2½ and 5 pounds of DDT per acre, gave a highly significant reduction in the number of plants killed by white-fringed beetle larvae. The average loss of stand due to beetle larvae was 22.5 percent in the untreated check plots, 5.5 percent in the plots receiving the 2½-pound DDT treatment, and 6.2 percent in the plots receiving the 5-pound treatment. Yields were secured in only 1 of the 3 tests, and both dosages of DDT were equally effective in increasing the yields. The average yield of seed cotton was 28 percent higher in the plots receiving the DDT treatments than in the untreated check plots.

DDT was applied in the drill rows in the plots of 2 tests (18 plots and 6 replicates of each treatment rate) planted to peanuts, and the initial population of larvae at planting time averaged 100 per square yard. Both dosages, 2½ and 5 pounds of DDT per acre, caused a highly significant reduction in the number of peanut plants killed by beetle larvae. The average loss of stand due to beetle larvae was 12.8 percent in the untreated check plots, 3 percent in the plots receiving the 2½-pound DDT treatment, and 1.8 percent in the plots receiving the 5-pound treatment. The yields of both peanuts and hay were greater in the plots receiving the 2½- and 5-pound DDT treatments than in the untreated check plots.

Larval populations were again determined in all plots in January or February 1947. DDT was applied to the drill rows at 2½ and 5 pounds per acre in the plots of 10 tests consisting of 90 plots, or, 30 replicates of each treatment rate. The average population at planting time in 1946 in the 90 plots was 113 larvae per square yard. The average larval population per square yard in January or February 1947 was 55 in the untreated check plots, 43 in the plots receiving the 2½-pound DDT treatment, and 34 in the plots receiving the 5-pound treatment. Both dosages caused a highly significant reduction in population of larvae. The 5-pound treatment was more effective than the 2½-pound treatment, and the difference between the two dosages was statistically significant.

The drill-row treatments with DDT were more effective in reducing subsequent larval populations in cotton and peanuts than in corn intercropped with velvetbeans. In the plots of 5 tests (45 plots and 15 replicates of each treatment rate) which were planted to corn intercropped with velvetbeans the average initial population of larvae was 118 per square yard. The average subsequent population of larvae per square yard was 56 in the untreated check plots, 59 in the plots receiving the 2½-pound treatment, and 45 in the plots receiving the 5-pound treatment. In the plots of 3 tests (27 plots and 9 replicates of each treatment rate) which were planted to cotton, the average initial population of larvae was 112 per square yard. The average subsequent population per square yard was 35 in the untreated check plots, 9 in the plots receiving the 2½-pound treatment, and 10 in the plots receiving the 5-pound treatment. In the plots of 2 tests (18 plots and 6 replicates of each treatment rate) which were planted to peanuts the average initial population of larvae was 100 per square yard. The average subsequent population of larvae per square yard was 81 in the untreated check plots, 50 in the plots receiving the 2½-pound treatment, and 43 in the plots receiving the 5-pound treatment.

In the plots which received applications of DDT in the drill rows only, the subsequent populations of larvae per square yard were determined in the drill rows, midway between the drill rows, and beside the rows (one-fourth the distance between the rows). The greatest reduction in subsequent population occurred in the drill rows, and neither dosage had any material effect on the populations beside or midway between the drill rows. The average subsequent populations in the drill rows were 46 in the untreated check plots, 19 in the plots receiving the 2½-pound treatment, and 11 in the plots receiving the 5-pound treatment; beside the rows 49 in the untreated check plots, 50 in the plots receiving the 2½-pound treatment, and 40 in the plots receiving the 5-pound treatment; midway between the rows 64 in the untreated check plots, 68 in the plots receiving the 2½-pound treatment, and 58 in the plots receiving the 5-pound treatment.

The broadcast treatments were more effective than the drill-row treatments in reducing subsequent populations of larvae. In the plots of 4 tests (36 plots and 12 replicates of each treatment rate) which were planted to corn with no intercrop the average initial population of larvae was 52 per square yard. The average subsequent populations were 42 in the untreated check plots, 14 in the plots receiving the 2½-pound treatment, and 10 in the plots receiving the 5-pound treatment.

Tests begun in 1947.--In 1947, 2 field-plot tests including 18 plots and 6 replicates of each treatment rate were started in which DDT was applied in the drill rows just prior to planting at rates of 2½ and 5 pounds per acre. All plots were planted to cotton, and the average initial population of larvae was 74 per square yard. The average loss of stand caused by white-fringed beetle larvae was 20 percent in the untreated check plots, 5 percent in the plots receiving the 2½-pound treatment, and 3 percent in the plots receiving the 5-pound treatment. The increase in yield of seed cotton was 3 percent in the plots receiving the 2½-pound treatment, and 20.8 percent in the plots receiving the 5-pound treatment.

Two tests were started in 1947 in which the DDT was applied broadcast to the plots at rates of 2½, 5, and 10 pounds per acre. For each test the plots were arranged in a 4 by 4 Latin square. The plots in one test were planted to corn with no intercrop and the average initial population of larvae was 68 per square yard. No loss of stand caused by the larvae occurred in any plot. The average increase in yield of ear corn per acre was 176 pounds (20.3 percent) in the plots receiving the 2½-pound treatment, 344 pounds (39.6 percent) in the plots receiving the 5-pound treatment, and 120 pounds (13.8 percent) in the plots receiving the 10-pound treatment. The plots in the other test were planted to soybeans, and the average initial population of larvae was 70 per square yard. Loss of stand caused by the larvae was light in the untreated check plots (only 0.4 percent), and negative in all plots receiving DDT treatments. The average yield in all the plots treated with DDT at the different dosages was less than in the untreated check plots. The decrease in yield per acre of soybeans was 21 pounds (4 percent) in the plots receiving the 2½-pound treatment, 119 pounds (22 percent) in the plots receiving the 5-pound treatment, and 108 pounds (20 percent) in the plots receiving the 10-pound treatment.

Effect of DDT Soil Treatments on Plants

From 1944 through 1947 information was obtained on the effect of soil treatments with DDT on the growth and yield of certain plants. This information was secured by the use of large earthenware pots, outdoor soil chambers, and field plots.

In field plots no injury or decrease in yield of cotton, peanuts, or velvetbeans resulted from soil treatments of $2\frac{1}{2}$ and 5 pounds of DDT per acre, and corn was not noticeably affected by treatments of $2\frac{1}{2}$, 5, and 10 pounds per acre. Cotton, corn, cowpeas, peanuts, velvetbeans, hairy vetch, oats, and blue lupine have been grown without any injury in outdoor chambers containing soil treated with as much as 50 pounds of DDT per acre. Injury to rye occurred from soil treatments of 10 pounds of DDT per acre when the rye was planted immediately or within 30 days after treatment, but not from soil treatments of 25 and 50 pounds of DDT per acre made 1 and 2 years before the rye was planted.

The growth of tobacco is apparently stimulated by treatments of the soil with as little as $2\frac{1}{2}$ pounds of DDT per acre. This condition was observed in both outdoor soil chambers and field plots. Tobacco plants grown in DDT-treated soil were more vigorous, and were larger than those grown in untreated soil. The effect of DDT soil treatments on the grade of tobacco has not been determined.

A few garden plants have been grown in earthenware pots or outdoor chambers in soil treated with DDT at rates of 10, 25, and 100 pounds per acre. The plants used in these tests were as follows: Collard, eggplant, onion, sweet pepper, strawberry, and tomato. The growth and yield of collards, eggplants, sweet peppers, and onions were not injured by the DDT treatments. Chemical analyses of the onions grown in soil treated at the above dosages showed no traces of DDT. The growth of strawberries was retarded by soil treatments of 100 pounds of DDT per acre when the plants were set 4 months after the treatments were applied, but dosages of 10 and 25 pounds were not harmful. Soil treatments of DDT applied 28 months prior to the setting of strawberry plants at rates of 25, 50, and 100 pounds per acre were not injurious to the plants.

The yield of tomatoes was definitely reduced by DDT soil treatments as low as 25 pounds per acre when the seeds were planted within 50 days of the DDT treatments, but not from soil treatments up to 100 pounds of DDT per acre made 2 years before the seeds were planted. In 1947 tomato plants were started in flats containing DDT at the rates of 10, 25, and 100 pounds per acre and transplanted to the field into untreated soil. The soil mixture used in the flats was half sandy loam soil and half well-rotted compost. In the flat receiving the 100-pound treatment the growth of the plants prior to transplanting was slightly retarded. The yield and earliness of fruiting were not affected by the DDT treatments.

The growth and flowering of chrysanthemum, pansy, petunia, verbena, and zinnia were not affected by dosages of 10, 25, and 100 pounds of DDT per acre.

The harmful effect of DDT soil treatments on tomatoes, rye, and strawberries greatly decreased or entirely disappeared, during 2 to 3 years following treatments. DDT applied to the soil in an emulsion was more harmful to rye and tomatoes than when applied as a dust. A highly purified DDT was less injurious to rye and tomatoes than a technical grade of DDT when both were applied as a dust, but when applied in an emulsion both grades of DDT were equally injurious.

SUMMARY

The toxicity of soil treated with DDT to white-fringed beetle larvae has been studied in earthenware pots, outdoor soil chambers, and field plots Newly hatched larvae are more readily killed by DDT in the soil than larger larvae, and partially grown larvae are more easily killed than mature larvae. DDT in the soil delays pupation and emergence. In pot tests using Tifton fine sandy loam a dosage of 10 pounds of DDT thoroughly mixed with 403.3 cubic yards of soil (the equivalent of a layer 3 inches deep on 1 acre) has given complete control of newly hatched larvae for a period of 3 years following treatment. Dosages of 1 and 2½ pounds gave 71 and 99 percent control the first year, but were less effective the second year when the 1-pound dosage gave no control and the 2½-pound dosage gave 86 percent control.

In outdoor chambers containing Tifton fine sandy loam heavy dosages of DDT applied on the surface and not mixed into the soil were not highly effective against the larvae. A dosage of 10 pounds of DDT per acre mixed into the upper 3 or 6 inches of the soil gave complete control of newly hatched larvae during a 2-year period following treatment. A dosage of 2½ pounds was less effective the second year than during the first year.

In field plots on Norfolk and Tifton fine sandy loam soil treatments of 2½ and 5 pounds of DDT per acre applied in the drill row or broadcast and immediately disked into the soil prior to or at planting time have reduced the damage by white-fringed beetle larvae to crops, increased yields, and caused a reduction in the subsequent populations of larvae. The broadcast treatments were more effective than the drill-row treatments.

Treatments of soil with DDT in excess of that required to give economic control of the white-fringed beetle have caused damage to only a few species of plants. Tomatoes, rye, and strawberries were the most susceptible plants tested. The harmful effects of DDT soil treatments on these plants greatly decreased or entirely disappeared during 2 to 3 years following treatments.